

Using a Near-Bed Sediment Flux Sensor to Measure Wave Formed Bedform Migrations and Formation Processes

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LONG-TERM GOALS

My research program focuses on identifying and quantifying sediment erosion, transport, and deposition processes on the continental shelf through state of the art observational techniques in both fine grained and sandy environments. In sandy environments, my goal is to understand the detailed interactions and feedbacks between hydrodynamics, bedforms, and the resulting sand transport. In fine-grained environments, I have been investigating the role fluid mud flows as a depositional mechanism in areas with high deposition rates. In both of these types of environments, I have also focused on relating the small-scale transport processes to larger temporal and spatial scale depositional and erosional patterns.

OBJECTIVES

The primary goals of this work are: 1) To quantify the role of near-bed sand flux in forcing the migration and geometric evolution of wave orbital scale ripples based on measurements from a near-bed suspended and bedload sediment flux sensor. 2) To study the interactions of the forcing hydrodynamics, sand transport processes, and bed geometry by determining how the hydrodynamic wave and current boundary layer structure over the bedforms is modified by the presence of different scale bedforms, and investigating the mechanisms by which bedload and suspended load transport is controlled by the forcing hydrodynamics over the bedforms.

APPROACH

The approach to meet the objectives outlined above combines field measurements, data analysis, and modeling. The field measurements (Figure 1) include measurements of bedform topography on a rapid enough time scale to observe ripple migration and temporal changes in geometry. This is conducted by using a rotary sidescan sonar system and a 2-axis rotary pencil beam sonar. Velocity and suspended sand concentration from the pulse coherent Doppler profiler measurements resolve the wave boundary layer and the lower portion of the current boundary layer, thus allowing estimates of sand flux in this region. Most significantly, a near-bed flux measurement allows investigation of the processes that force bedform formation and migration (*Traykovski, 1998 Traykovski, 2005*). The conceptual basis for this type of measurement is that the stationary bed does not produce a Doppler shift and grains moving immediately above the bed produce a measurable Doppler shift. This near bed flux is difficult to resolve spatially from the stationary bed, but can be resolved by Doppler shift. The observational portion of the work took place at the Martha's Vineyard Coastal Observatory (MVCO) to take advantage of the power supply and data communication from the cabled node.

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The modeling portion of the work combines analytical and empirical models along with numerical simulations. The analytical modeling includes examining the application of steady flow bedload models, such as the Meyer-Peter Muller Bedload model, to wave forced fluxes over ripples and the resulting time scales for ripple geometry evolution. The numerical simulations are being conducted in collaboration with H. Jiang at WHOI and involve comparing the observations to Large Eddy Simulation (LES) predictions forced with observed free stream velocities.

WORK COMPLETED

The bistatic Doppler system developed in 2002 was transitioned into a field deployable system in 2003. It has been deployed on a quadpod along with a 2-axis pencil beam sonar, a rotary fan beam sonar, and an ADV to measure bedform evolution along with the hydrodynamic and sediment transport forcing processes. In the July, 2003 the system was deployed in coarse sand, which supports large orbital ripples, 100 m from the MVCO node. Unfortunately, cable technical problems and subsequent node failure only allowed 4 bursts of data during active ripple conditions. In December, 2003 the system was redeployed on a short cable, in fine sand near the MVCO node at the same time as the mine burial program was being conducted. A four month data set, with several energetic wave events over 3 m wave height, was recorded during this deployment. In 2004 the system was upgraded with an armored fiberoptic cable to allow access to the coarse sand and avoid the cable failure modes that were previously experienced. The system was successfully deployed in coarse sand from Sept 05 to April 06 and delivered usable data for 70% of that period including several events of over 4 m wave height. The remaining 30% of the data was contaminated by biofouling.

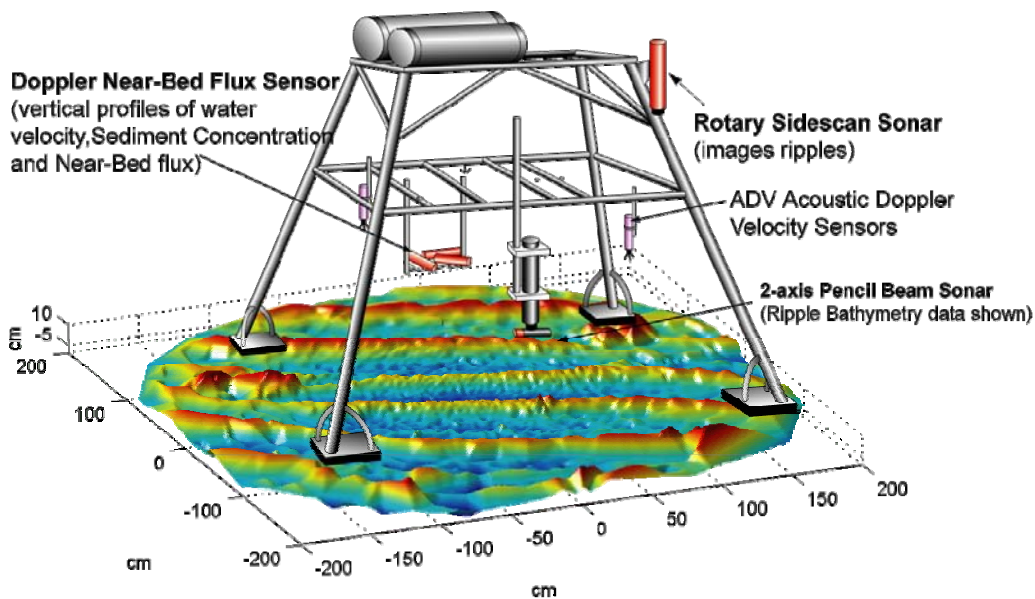


Figure 1. A instrumented frame with a 2-axis pencil beam sonar to map ripple bathymetry as shown, a rotary fanbeam sonar to map the larger scale distribution of ripples in the vicinity of the frame, an ADV to measure waves and currents, and a bistatic Doppler profiling system to measure near bed sediment flux.

RESULTS

Analysis of the 2003 coarse sand and 2004 fine data sets focused on comparing the pulse coherent Doppler profiles of velocity, backscatter and sediment flux from the two sites (see 2004 annual report). Not unexpectedly, the data showed that near bed wave-forced flux is the dominant transport mechanism in coarse sand, and that suspended transport is more important in fine sand. In the fine sand both wave-forced suspended net transport components and mean current forced components appear to be important (*Traykovski, 2005*). Analysis of the 2005 data in coarse sand so far, has focused on the temporal evolution of ripple geometry. The data was used to test and calibrate a recently developed time dependent model for ripple evolution (*Traykovski, submitted*). The 2-axis pencil beam sonar data allows estimation of the wavenumber spectrum of ripple elevation and the model predicts the same quantity. This data set, along with previous rotary sidescan data sets from the MVCO and LEO-15 sites show the relict ripple left after storm typically have 0.7 to 1.5 m wavelength. The spectra from the 2-axis sonar data set shows that these relict ripples often have bimodal spectra. While previous ripple models that assume the ripples were in equilibrium with forcing predict short wavelength relict ripples (0.2 to 0.4 m) and unimodal spectra, the temporal delay in the new model allows the model to predict both long wavelength relict ripple and bimodal spectra (Figure 2). The temporal delay time scale is calculated from the ratio of ripple cross-sectional area to the maximum flux rate in a wave cycle.

IMPACT/APPLICATION

The ability to quantify flux near the stationary bed has potential to increase our understanding of bedform processes. The analysis described above uses the transport rate to estimate the time scale for adjustment of bedforms in response to changes in hydrodynamic forcing. Accurately quantifying this time scale is essential to successful prediction of relict ripple geometry. Also, basic modes and directions of wave-forced sediment are poorly understood over bedforms (*Traykovski et al., 1999*). For instance, the transition from onshore bedload dominated flux to offshore suspended flux has not been well quantified. The long time series measurements in coarse sand have potential to address these issues.

RELATED PROJECTS

This project is closely related to work that has been conducted as part of the RipplesDRI/SAX04 project. In that project the ripple model discussed here was used to examine relict ripples formed on the western Florida shelf due to waves generated by Hurricane Ivan. The 2003 and 2004 work was related to several projects associated with the mine burial prediction program as those data sets were collected at the time as a major mine burial experiment at MVCO. This data set provides background bedform measurements in absence of mines. This was found to be particularly important in coarse sand as it was found that the depth on mine burial in the presence of large wave orbital ripple is related to the height of the bedforms (*Traykovski et al., In Press*). The pulse coherent Doppler technology used in this project is currently being applied to the development of a battery powered autonomous system that will be able to make measurements in environments where a cable to shore is not possible.

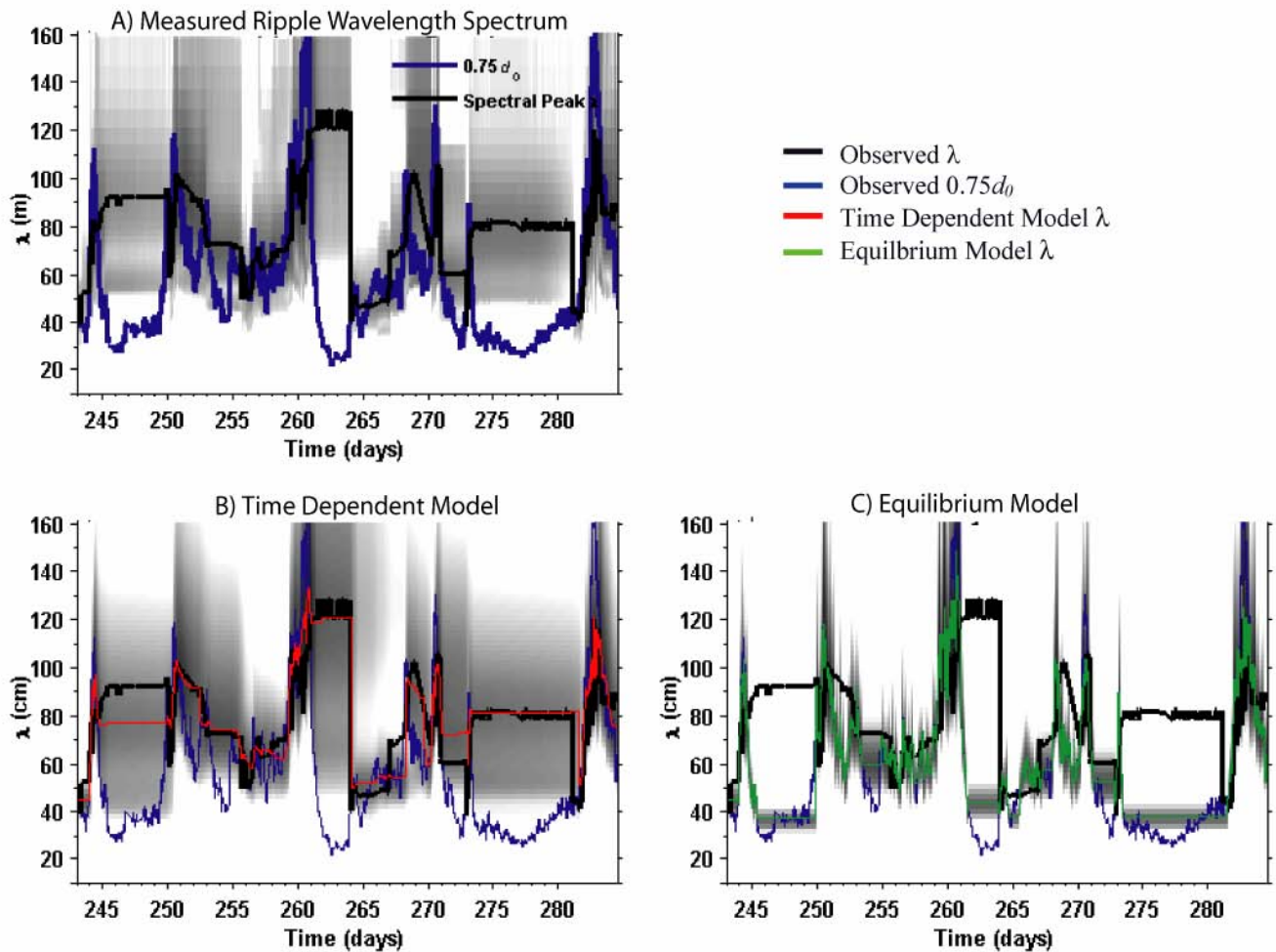


Figure 2. *A) Measured ripple spectra (gray color scale), ripple wavelength as estimated by the peak of the spectra, and scaled orbital diameter forcing time series. B) Predictions of ripple spectra and peak wavelength forced by the measured orbital diameter from the time dependent model. C) The same quantities from a equilibrium ripple model. The time dependent model predicts spectral bandwidths, and long wavelength relict ripples consistent with the observations.*

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